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Investigation on Ultrahigh Heat Flux of Nanoporous Membrane Evaporation Using Dimensionless Lattice Boltzmann Method

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Abstract : Thin liquid film evaporation in ultrathin nanoporous membranes, which reduce the viscous resistance while still maintaining high capillary pressure and efficient liquid delivery, is a promising thermal management approach for high-power electronic devices cooling. Given the challenges and technical limitations of experimental studies for accurate interface temperature sensing, complex manufacturing process, and short duration of membranes, a dimensionless lattice Boltzmann method capable of restoring thermophysical properties of working fluid is particularly derived. The evaporation of R134a to its pure vapour ambient in nanoporous membranes with the pore diameter of 80nm, thickness of 472nm, and three porosities of 0.25, 0.33 and 0.5 are numerically simulated. The numerical results indicate that the highest heat transfer coefficient is about 1740kW/m^2·K; the highest heat flux is about 1.49kW/cm^2 with only about the wall superheat of 8.59K in the case of porosity equals to 0.5. The dissipated heat flux scaled with porosity because of the increasing effective evaporative area. Additionally, the self-regulation of the shape and curvature of the meniscus under different operating conditions is also observed. This work shows a promising approach to forecast the membrane performance for different geometry and working fluids.

Keywords : high heat flux, ultrathin nanoporous membrane, thin film evaporation, lattice Boltzmann method
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